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PERMANENT INTERNATIONAL ASSOCIATION
OF
CONGRESSES OF NAVIGATION

# INLAND NAVIGATION

# Notice on the Reconstruction of the NEW TROLLHÄTTAN CANAL connecting the Lake Vänern and the Kattegat

BY

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Plate I: Map of the Canal.

# NOTICE ON THE RECONSTRUCTION
# OF THE
# NEW TROLLHÄTTAN CANAL

connecting the Lake Vänern and the Kattegat

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## 1. — THE NEW TROLLHATTAN CANAL

The Royal Board of Highways, Private Railways and Water Constructions submitted in 1902, at the Commission of the Government, a Draft of a proposal for an improved waterway between Lake Vänern and the Kattegat. This proposal was drawn up by *Lieutenant-Colonel P. L. Laurell*, of the Corps of Royal Engineers, and was recommended, with certain modifications, by the said Board. The matter was submitted to various authorities for their opinion. The Board of the Royal Trollhättan Canal and Water Works — in 1909 reorganized as the Royal Board of Waterfalls — delivered its opinion on the 18th of December 1908, based on a Memorandum by *Colonel F. V. Hansen*, then managing director of that Board, and now Director-General of Waterfalls, accompanied by a detailed Report, drawn up mainly by *Captain G. Malm*, who was then superintending the construction of the Trollhättan Power Works.

At the suggestion of the Trollhättan Board, its proposal was further examined by a special Commission, composed of representatives of all the interests affected by the Canal and of all the competent State departments. The proposal having been recommended by the Commission, a Government Bill on the subject was laid before the Riksdag (the Swedish Parliament). In view of this Bill, the Riksdag resolved to vote a grant of 22.800.000 Kronor for the construction of a new waterway between Vänersborg and Gothenburg, mainly in conformity with the proposal drawn up by the Board of the Royal Trollhättan Canal and Water Works. The following conditions were, however, laid down : firstly that certain places on Lake Vänern should arrange harbours to receive vessels of the maximum size which could pass the canal when reconstructed, and secondly that the city of Gothenburg, through whose harbour the canal passes, should itself undertake the excavations of its own harbour, to the required depth. Guaranties having been obtained for the fulfilment of these conditions, the work was started at the end of 1909.

## 2. — TECHNICAL REGULATIONS FOR THE NEW CANAL

The actual canal is constructed for vessels with a draught of 4 metres, the locks for vessels with a draught of 5 metres. Also the openings through the bridges are calculated for vessels of the latter size, besides which certain portions of the canal — where future excavating to a greater depth and breadth, if executed while the canal was in use for traffic, would have entailed heavy expense — were constructed from the very outset for a draught of 5 metres. This is the case, for instance, with Stallbacka Canal above Trollhättan and the portion immediately north of the street bridge at Trollhättan.

The technical regulations laid down for the New Canal are shown in the Table below.

The lesser bottom-width of the canal, viz. 24 metres, has as a general rule been adapted to artifical reaches. This width does not allow vessels of the largest size to pass one another, but is equivalent to a double channel for vessels with a breadth of 9 metres, which was considered sufficient for the most immediate requirements. In order to allow larger vessels to pass one another, a sufficient number of passing places have been arranged in these portions of the Canal.

| DESIGNATIONS | Greatest Depth of Navigation | |
|---|---|---|
| | $4^{m}00$ | $5^{m}00$ |
| | metres | metres |
| Bottom width in artificial canal at least . . . | 24.00 | 24.00 |
| Bottom width in artificial canal at passing place. | 29.00 | 35.00 |
| Bottom width in river or lake . . . . . . . | 40.00 | 48.00 |
| Minimum depth of water of blasted canal . . . | 4.40 | 5.50 |
| » » » excavated canal with firm bottom . . | 4.40 | 5.50 |
| » » » with soft bottom . . | 4.80 | 6.00 |
| » » » in river or lake . . | 4.80 | 6.00 |
| *Maximum permissible speed of vessels :* | knots | knots |
| In river or lake . . . . . . . . . . . | 8 | 9 |
| In artificial canal (for vessels of largest size) . . | 3 | 3 |
| *Minimum radius of curvature* at entrance to lock . . . . . . . . . . . . . | metres<br>500.00 | metres<br>500.00 |
| *Minimum depth of water* at sill. . . . . . . | — | 5.50 |
| *Width at opening* of lock gates . . . . . . . | — | 13.70 |
| *Length of lock chambers* . . . . . . . . . | — | 90.00 |
| *Length of lock* from gate to gate . . . . . . | — | 97.90 |
| *Total section* of 2 lateral culverts at locks. . . | — | 9.5 to 11.5 |

## 3. — **EXTENT OF THE CANAL**

(Plate I.)

The entire length of the canal is about 84 kilometres. The tracé of the canal below Brinkebergskulle follows in the main the course of the River Göta, and runs through the actual bed of the river for a reach of no less than about 75 kilometres. The difference in level between Lake Vänern and the sea is at mean water 44.35 metres; concentrated waterfalls which constitute impediments to shipping occur at the following places : just below the exit of the river from Lake Vänern, on the reach from Källshagen to Vargön, drop 5.7 metres; at Trollhättan, drop previous to the reconstruction of the Canal 32.6 metres; at Akerström, drop previous to the reconstruction 1.0 metre, and at Lilla-

Edet, drop previous to the reconstruction 3.5 metres. The remaining difference in level has been more or less evenly distributed between the reaches of river situated between the concentrated falls; these reaches had in fact been used without difficulty by the previous canal traffic.

The Källshagen-Vargön Fall was circumvented by the old Canal by an artificial channel, 4.2 kilometres in length from Lake Vänern at Vänersborg through the little lake of Vassbotten and thence through the narrow passage called Karlsgrav (Charles Trench), direct to the River Göta at Brinkebergskulle. The drop was surmounted by two locks, separated by an intermediate basin. The New Canal likewise follows the course of Karlsgrav, which has been widened to the required breadth. Past Vänersborg an entirely new channel has been made west of the old one. The drop in the new Canal remains as before, except at low water; but now only one lock has been constructed for the entire fall, placed approximately halfway between the two former ones, the upper one of which has been dismantled. In connection with the lock has been constructed a stone-fill dam to cut off the valley through which the artificial canal is drawn.

For Brinkebergskulle to Trollhättan, 7.0 kilometres, the Canal follows the course of the river except for a reach of about 1.3 kilometres past Stallbacka, where the river has by nature a very wide but shallow section, whence an artificial channel previously existed. Here too the former reach has been retained, but in order to attain sufficient depth at low water, without incurring too great expense of construction, the low water-level of the river above Trollhättan has been raised about 40 centimetres by damming the water at the regulating dam at Trollhättan which had already been executed for the purpose of the Power Works, besides which the old Stallbacka Canal was enlarged and deepened.

Formerly the traffic was led past Trollhättan into a channel about 2 kilometres in length cut through the east bank of the river, and terminating in a little lake called Akersjö. From the latter two sets of locks, that of 1844 with 11 locks, and that of 1800 with 8 locks, led down to the river.

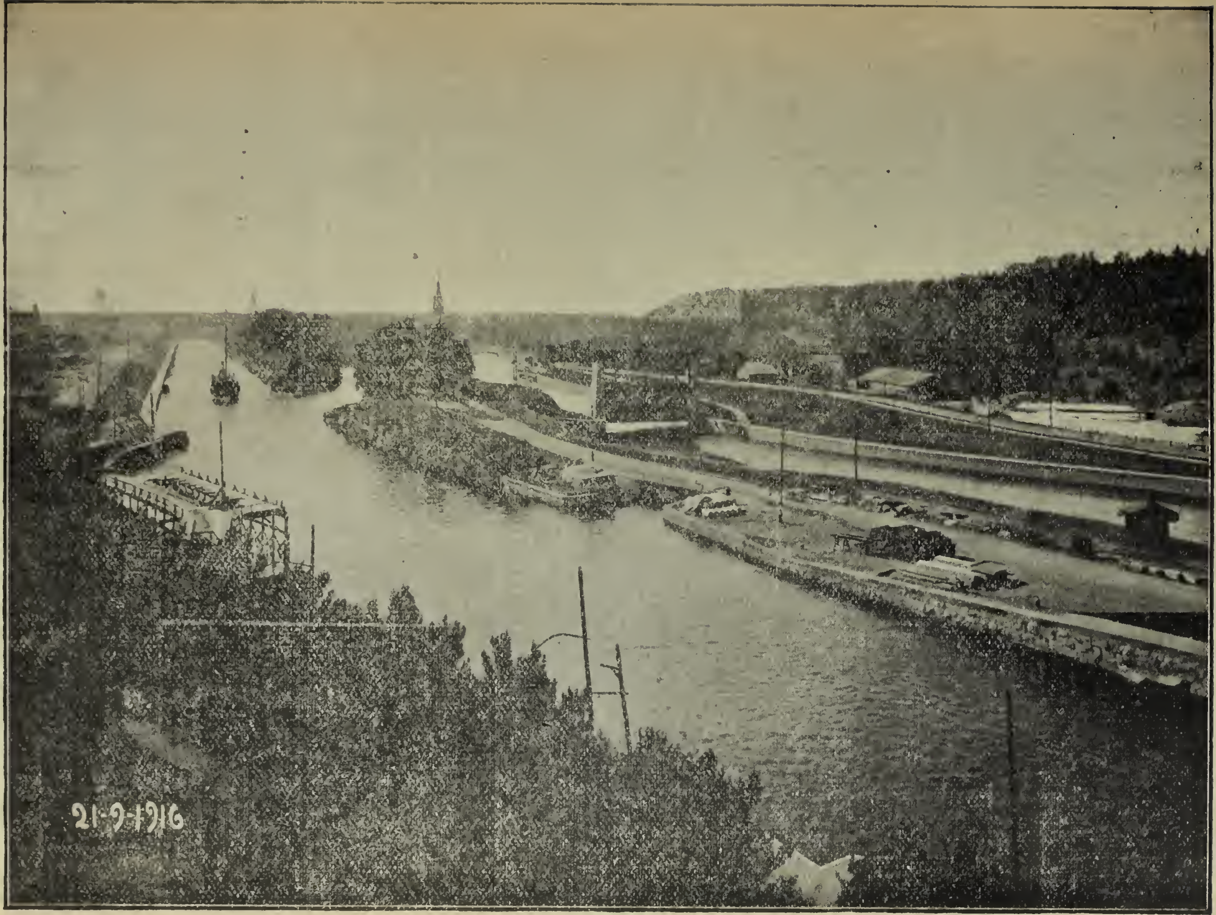

*Fig. 1.* General view of the new waterway, showing the administration building of the Trollhättan Canal and Waterworks

The new Canal follows in the main the course of the old one down to Akersjö, where, however, the requisite widening, straightening, and deepening had to be undertaken. Along the south part of the street called Osterlanggatan in Trollhättan an entirely new channel was laid out, in order to attain a straighter reach. From Akersjö a set of four locks has been constructed in a new direction down to the River; the first three of these locks are coupled together and separated from the upper one by an intermediate basin.

Below Trollhättan down to Lilla Edet the profile of the River has been altered by the erection of a dam at Lilla Edet, which dams up the water to such a height that the drop at Akerström and also, to a small extent, the drop at Trollhättan situated below the great Power Station, is transferred to Lilla-Edet. The rapids at Akerström have been cleared, so that the navigation can proceed in the River without the aid of locks, and thus the whole reach of the River from the locks at Trollhättan to Lilla Edet is navigable. The drop at Lilla-Edet after this alteration of profile is 5.45 metres instead of 3.5 metres as before. The drop was formerly surmounted by means of two locks, arranged on the left bank of the River and separated by an intermediate basin. In the new Canal these two locks have been replaced by one lock, situated close to the upper of the two former ones. Above and below the new lock channels lead down to the River. The artificial reach past Lilla Edet has a total length of about 1 kilometre.

Below Lilla Edet the Canal follows entirely the course of the River. The works that have been executed here have consisted mainly in straightening the channel by the removal of certain projecting points and submerged rocks, and in the dredging of a deeper channel.

## 4. — ADMINISTRATION AND EXECUTION OF THE WORK

As has been already mentioned, the proposal, passed by the Riksdag, for a new Canal between Vänersborg and Gothenburg was drawn up by the Board of the Trollhättan Canal and Waterworks, but the further management and the execution of the work was entrusted to the Board of Waterfalls, established from the 1st January 1909, within whose purview also fall questions concerning canals, in so far as the Government may so determine.

The chief superintendence of the entire work was thus in the hands of the Director-General of Waterfalls, *Colonel F. Wilhelm Hansen.*

The supplementary investigations required for the elaboration of the definite plan were set on foot as early as the summer of 1909. These investigations, as well as the work of elaborating the proposal of the Trollhättan Board under the superintendence of the Director-General of Waterfalls, were mainly entrusted to *Captain G. Malm*, of the Corps of Royal Engineers, who had previously superintended the construction of the State Power Works at Trollhättan.

The work itself also was placed under the management of Captain Malm, who until the 1st October 1910, was Superintendent and then Chief Engineer, to the Building Department of the Board of Waterfalls till the 1st August 1914.

The Superintendent of the works during the years 1911-1914 was *Lieutenant A. Ekwall* of the Corps of Royal Engineers, who was appointed Chief Engineer to the Building Department on the 1st August, when Captain Malm retired from the service of the State.

Mr. *N. K. Sundblad*, Civil Engineer, was at the same time appointed Superintendent of the reconstruction of the canal.

## 5. — **THE EXCAVATING, BLASTING AND DREDGING WORKS**

*The excavating works.* — The excavating works have as a general rule been of a simple nature, and of a relatively small extent, whence it was not necessary to make any exceptional arrangements for their execution. The same transport arrangements were employed, as a rule, for the earth stuff as for the blasted stone, inasmuch as rock had generally to be blasted in the same shaft, after the covering layer of earth had been removed. As a general rule the earth was excavated by hand; however, considerable quantities of clay at the shaft intended for the Ström lock were removed by means of an excavating machine on the Paternoster principle.

The excavations at, and below, the Ström lock were in fact attended by considerable difficulties, inasmuch as rather extensive landslips occurred in the earth masses consisting of soft clay, which fact also occasioned the use of very flat slopes in this portion of the work.

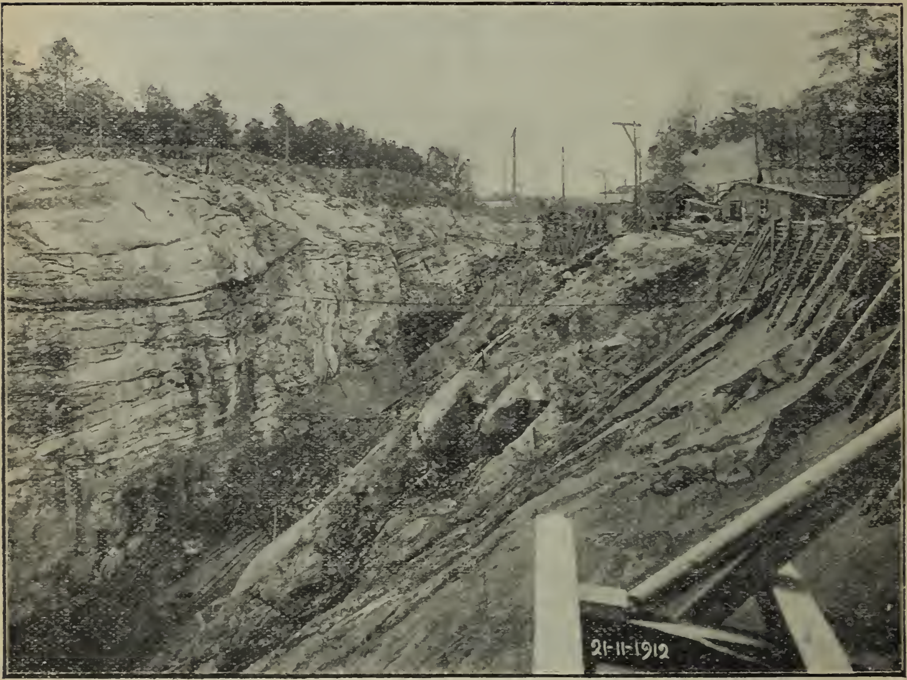

*Fig. 2.* Excavating for the construction of the flight of locks at Holmen.

Alltogether 712,455 m³ of different kinds of soil were removed in the excavations.

*Blastings of Rock above Water.* — The blastings of rock which were necessary in constructing the Canal were very extensive. Alltogether 1,033,882 m³ of solid rock were blasted, 26,152 m³ of this total being sub-water rock. At all the locks large masses of rock had to be removed : at the flight of locks alone, 296,095 m$^3$; otherwise the largest amounts of rocks occurred along the so-called « rock-canal » (bergkanalen) between

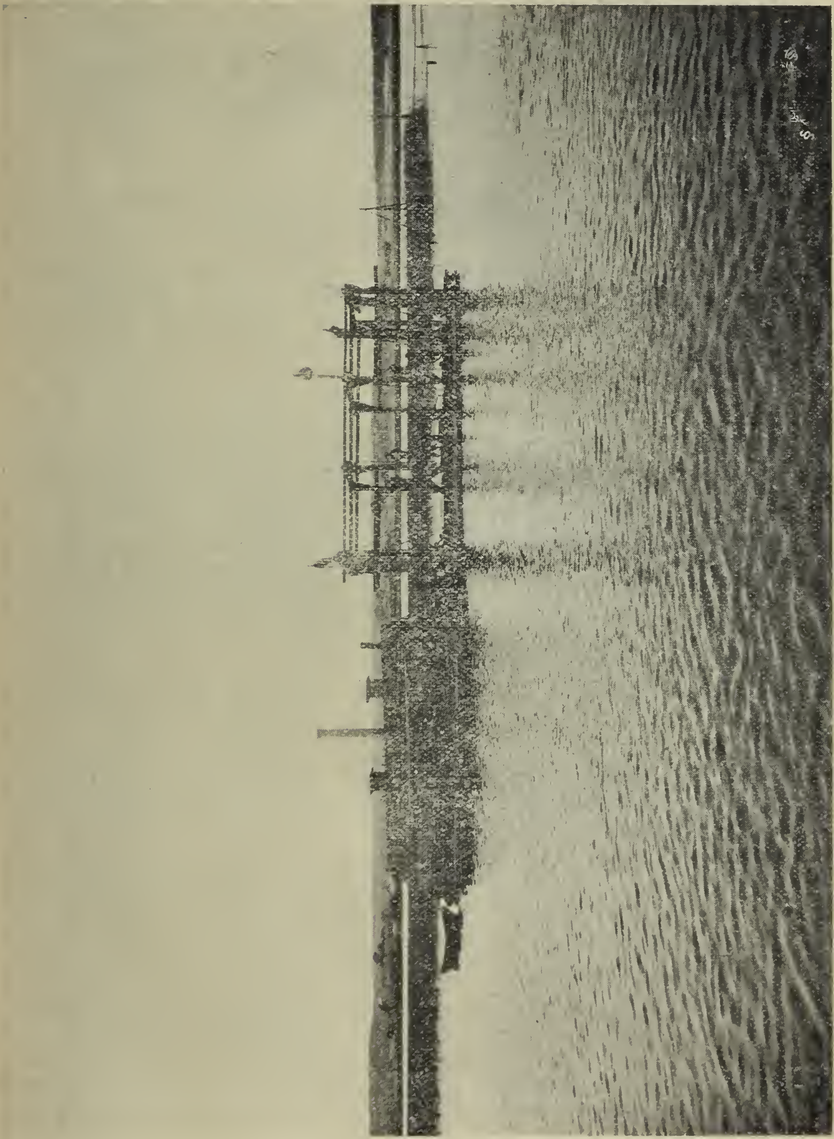

*Fig. 3.* Drilling-platform. — Barge with steam-boiler and auxiliary machinery.

the Trollhättan swing-bridge and Akersjö, above all on the new portion of the Canal along Osterlänggatan. Machines were employed to a very large extent in the blasting, being mostly driven by electric power from the Trollhättan Power Works.

In all the high rock shafts the rock was cut into stopes, ranging between 6 and 8 metres in height.

In order as far as possible to enable the work to be carried out in dry shafts, extensive coffer-dam works were executed in several places.

*Sub-Water Blasting.* — It was obviously impossible to avoid sub-water blastings, allthough their extent was restricted in various ways. Alltogether 26,152 m³ of rock were blasted under water. In this work were employed, as a rule, *drilling machines* driven by stream (fig.3) erected on rectangular rafts which could be firmly shored to the river bottom by means of movable legs of timber at their corners and which were supplied with steam from a « steam barge », specially equipped for the purpose. The drilling was carried out through pipes projecting above the surface of the water, and the dynamite charges were also laid through pipes. The discharge of the blasting shot, by electric ignition, was effected for a whole series of blasting-holes in a single « volley », and the blasted rock was removed with a single-bucket dredger or organe-peel grab.

*The Dredging Works.* — Also the dredging works were very extensive, no less than 2,364,312 m³ of solid stuff having been excavated. The bulk of this consisted of clay, but also large quantities of chessom, gravel, and stone were fetched up by the dredging-machines.

The masses of earth brought up by the dredges were partly dumped into deep places in the Stora Vassbotten Lake, the River Göta, and into the Dana Fjord (near Gothenburg), but were also, to a great extent, washed ashore with the aid of dredger elevators, whereby various low-lying districts along the canal were silted up, so that they could be utilized for the purpose of storage or for agriculture. Thus, for instance, a large harbour area, belonging to the city of Vänersborg, between the old and the new Canal, was filled up with silted mud.

## 6. — BREAKWATER AT VÄNERSBORG

At the entrance of the Canal from Lake Vänern was erected a new breakwater, which, together with the two old breakwaters, affords the entrance channel excellent protection against northern and north-easterly storms.

## 7. — DAMS

In connection with the Canal two dams were erected, viz. an earth dam at Brinkebergskulle, and a regulating dam at Lilla Edet.

*The dam at Brinkebergskulle* is a solid dam, consisting of two parts, one on the east and one on the left side of the lock. Its object was to enable the water surface above the lock to be dammed up flush with the level of Lake Vänern. The east part of the dam is placed across a valley which extends from the basin above the lock and down to the River Göta at Restad. The west dam is placed across the bed of the old canal. Both the dams consist of rock embankments filled up with earth and with tightening on the upper side. In the east dam it was found possible, by dint of repeated blasting from below to embed the rock embankment about 10 metres into the layer of clay, which is here about 20 metres in depth. In the west dam the rock embankment reposes on clay, which there is able to support it.

At the east dam the tightening has been attained by a sheet-piling at a distance of about twenty metres in front of the crown of the rock embankment, and with the upper edge a little above the surface at high water. The sheet-piling is shored to the stone bank by means of rod irons and the backfilling next to the piling consists of a layer of well packed chessom to an average thickness of 1.5 metres. The space between the chessom and the stone bank has been filled with earth.

The side of the rockembankment which faces upwards has been provided with a stone glacis.

At the east dam the caulking consists of a kneaded layer of clay, at the bottom deposited between two walls of sheet-piling, rammed down to solid bottom, and, on the top of that sloped up against the rock embankment, on the top of that a layer of earth filling.

In the western dam is built an ice outlet having a clear width of 5 metres, with a horizontally divided flood-gate. Each leaf of the flood-gate consists of a frame of iron beams with a boarding of timber. The operation is effected by a hand-windlass.

*The Lilla Edet Dam.* The regulating dam at Lilla Edet, whose object is to dam up the water surface of the River Göta to such a level that after the rapids at Akerström have been duly cleared the water surface of the river shall be given a uniform and gentle incline from the foot of the Trollhättan Falls (Olidohalan) down to Lilla Edet, consists of three parts, namely :

The dam proper across the bed of the River;

The dam in front of the entrance to the Inland Pulp Mill, and

The bank protector in front the intake to the Lilla Edet Paper Mill.

The dam across the bed of the River consists of two sluices each with a clear width of 22 metres, which can be shut off by rolling dams.

The dams in front of the Inland Pulp Mill and the Lilla Edet Paper Mill consist of ordinary flood-gate dams, their object being to enable the working of the factories to be continued.

## 8. — BRIDGES

The Canal is crossed by nine bridges, viz:

The Dalbo Highway Bridge at Vänersborg ;

The Vänersborg Railway Bridge (fig. 4), for the Uddevalla. Vänersborg and Herrijunga Railway ;

The Grop Bridge for a highway at the upper end of Karlsgrav;

An emergency dam-bridge in the central part of Karlsgrav (at Fridhem);

The Railway Bridge for the Bergslagen Railway at Trollhättan;

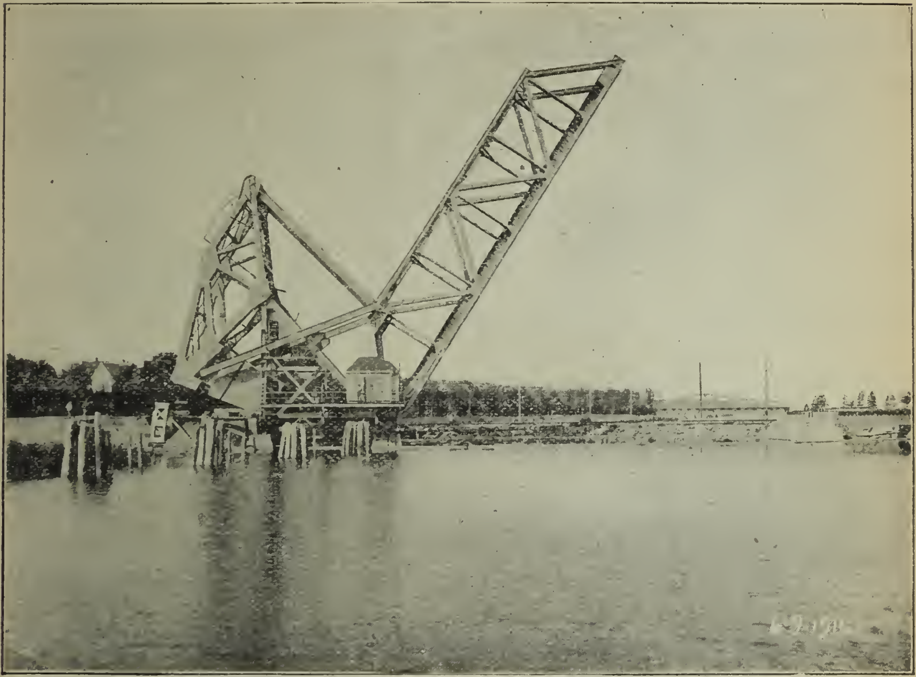

*Fig. 4.* Single leaf bascule railway-bridge, at Vänersborg.

The Street Bridge at Trollhättan (fig. 5);

The Railway Bridge, for *Nydqvist and Holm's Railway* at Trollhättan;

A combined dam- and road bridge at the upper end of the lock at Ackersberg, and

A combined dam- and road bridge at the upper end of the lock at Ström.

The different types of bridges employed were the following: Double-leaf swing-bridge, as regards the Dalbo, Grop and Bergslag. Railway bridges;

Single-leaf bascule bridges, in the case of the Vänersborg Railway Bridge and the Bridge at Ström;

Double-leaf bascule bridge, as regards the Trollhättan street bridge, and single-leaf swing-bridge, for the bridges at Karlsgrav and the Ackersberg lock, as well as the bridge for Nydqvist and Holm's railway.

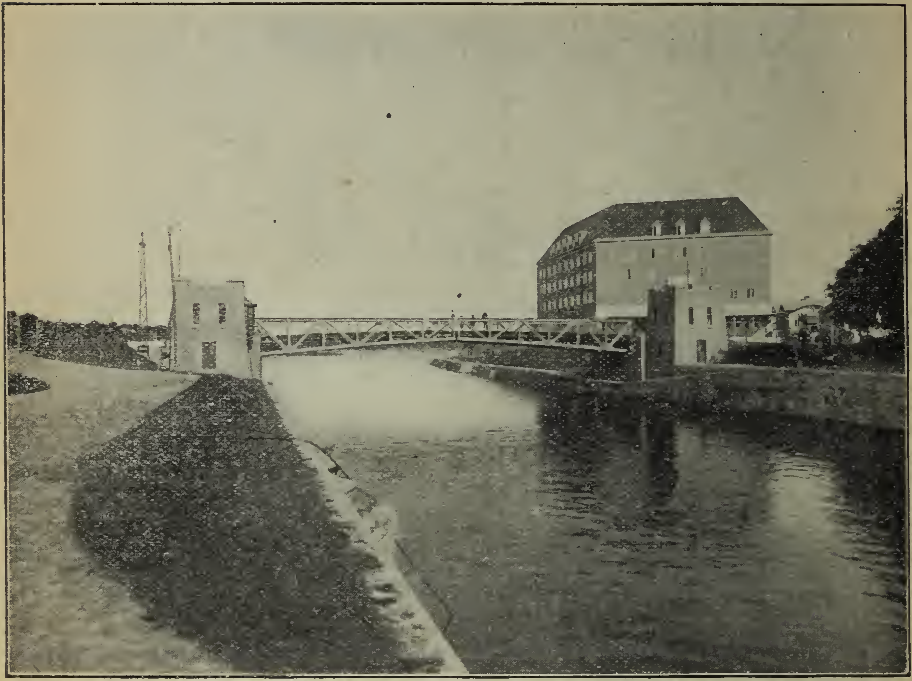

*Fig. 5.* Double leaf bascule bridge, at Trollhättan.

## 9. — THE LOCKS

The Canal has six locks, one at Brinkebergskulle, four at Trollhättan and one at Ström. Out of the four locks at Trollhättan the three lowest are coupled into a flight (fig. 6) which is separated from the uppermost lock by an intermediate basin (fig. 7).

The drops of the locks vary with the level of the water in the River. At mean water the locks have the following drops :

| | |
|---|---|
| Lock N° 1 at Brinkebergskulle . . . . . . . . . . | 5.7 m. |
| Lock N° 2 at Ackersberg (Ackersjö) (fig. 8) . . . | 7.95 m. |

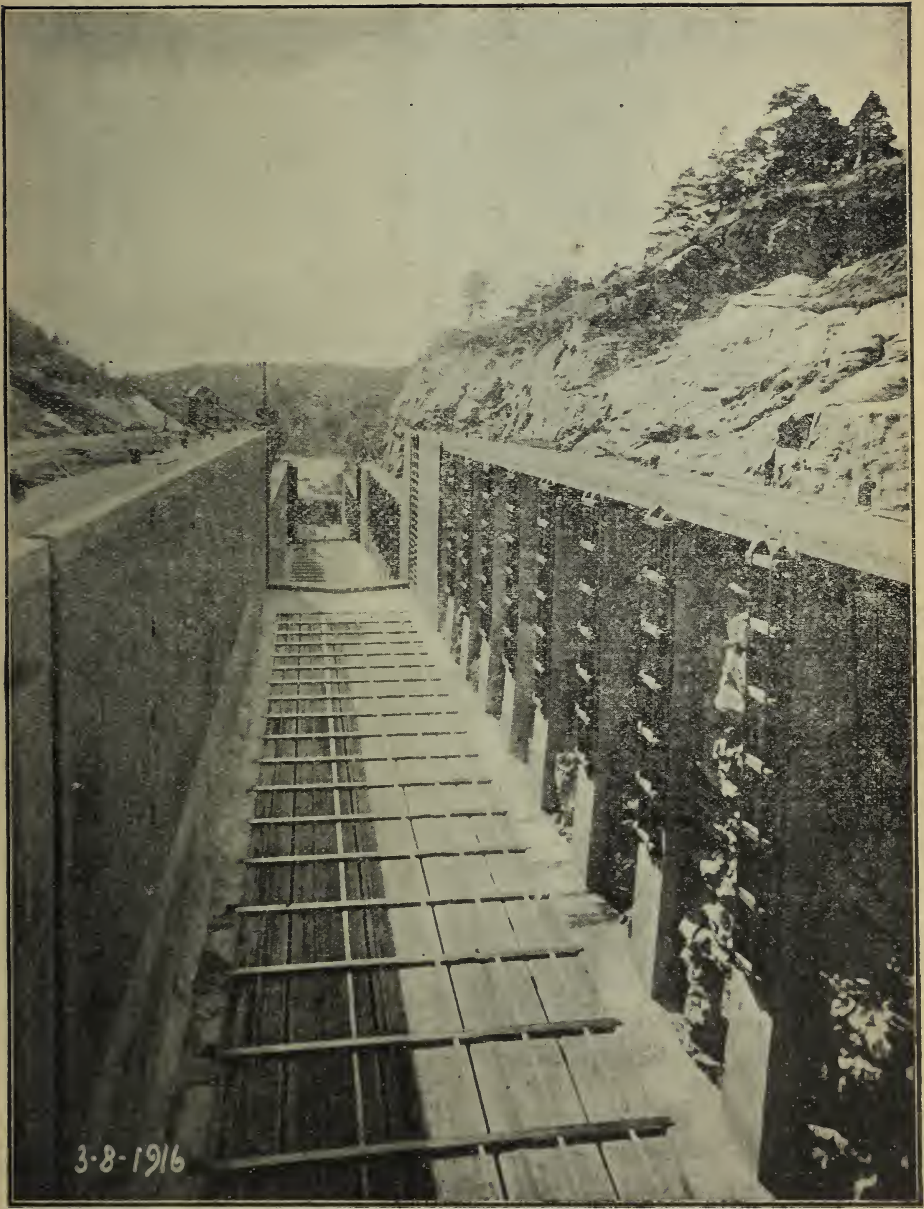

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*Fig. 6.* New flight of locks at Holmen (view from the upper side).

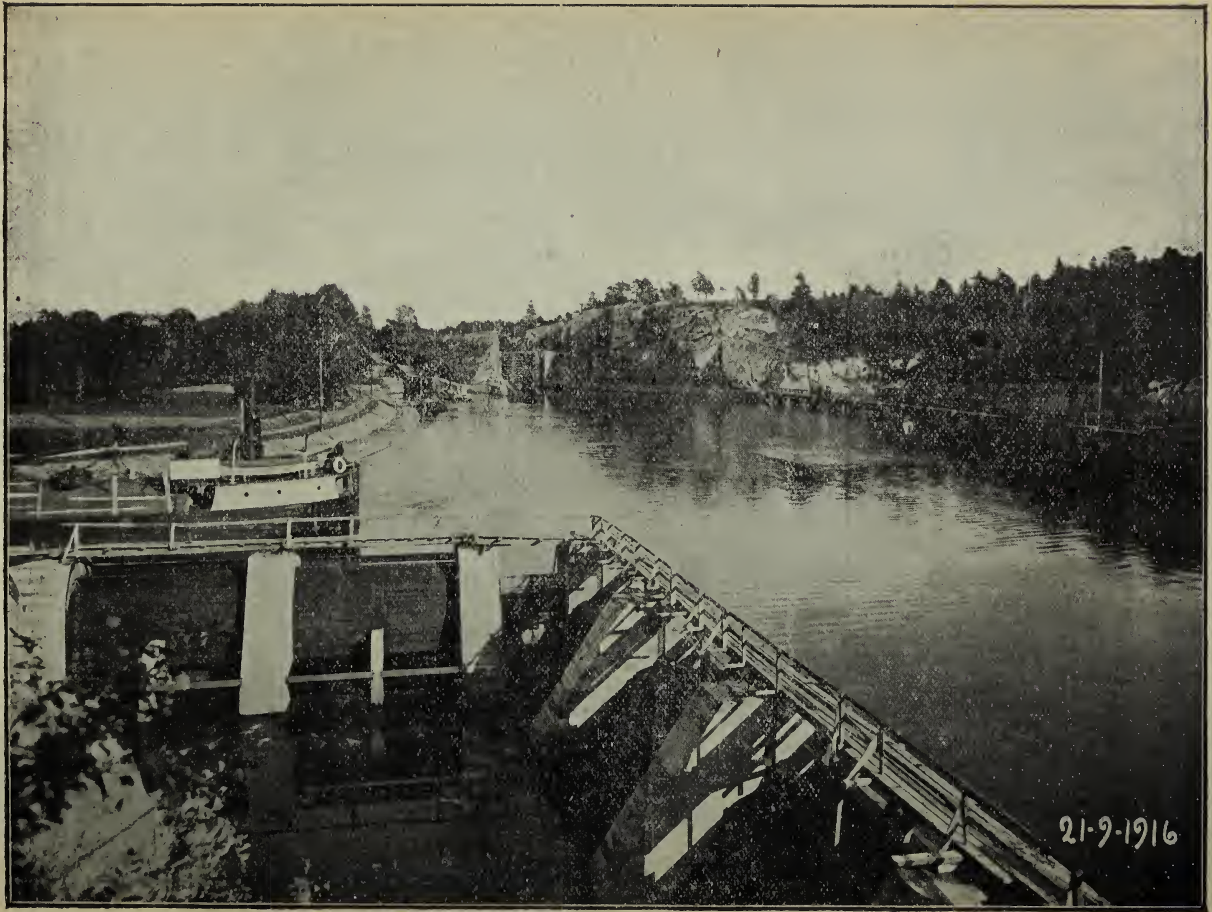

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*Fig. 7.* Intermediate basin below the lock nº 2, with overfalls and siphons at the fore part of the view.

| | |
|---|---|
| Lock N° 3 at the basin above the flight of locks | 7.88 m. |
| Lock N° 4 at « Mellenslussen » | 7.82 m. |
| Lock N° 5 at Holmen | 7.87 m. |
| Lock N° 6 at Ström | 5.4 m. |

The greatest drop is obtained at the Akersjö lock, where at high water above the lock, and at low water below it, it may amount to 9.5 m

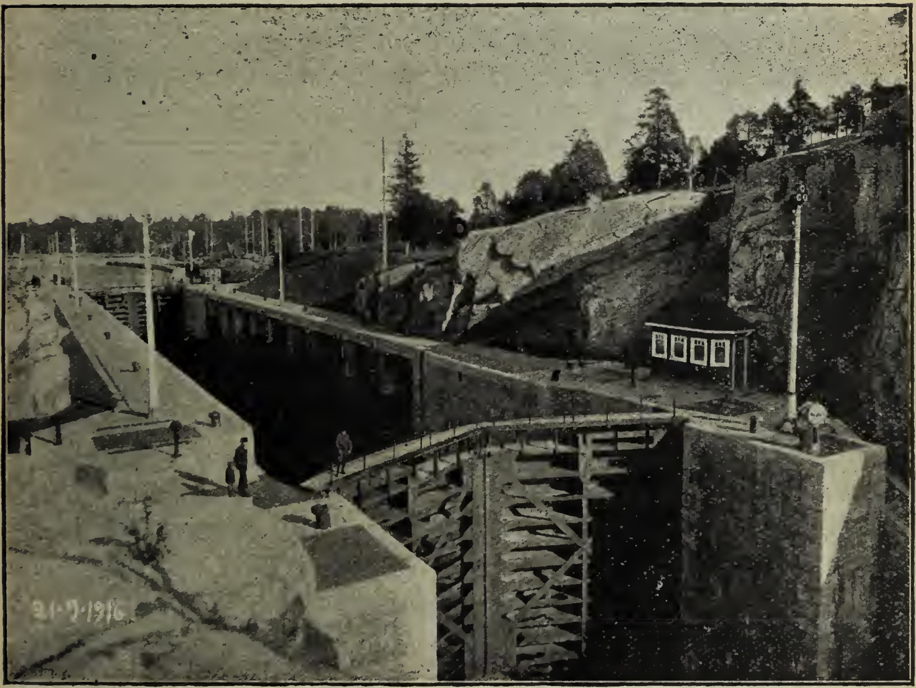

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*Fig. 8.* Lock n° 2 at Ackersberg, of 7$^{m}$95 lift (view from the lower side).

The locks are constructed as chamber locks, and thus consist mainly of a basin arranged between vertical side walls, which can be closed at the ends by gates. Te lock chambers can be supplied with and emptied of water by lateral culverts arranged in the masonry on the sides of the gate chambers. The lateral culverts are placed on either side of the lock basin, except as regards the Akersberg lock, where the inlet tunnels have been placed only on the east side of the lock, and in that of the Holmen lock, where the outlet tunnels have been placed only on the west side of the lock. The inlet culverts debouch into a « crypt », arranged under the upper gate chamber in each lock. From the crypt a bottom channel leads under the bottom of the lock, from which the water flows out into the lock.

The outlet tunnels proceed likewise from the bottom channel. The flow of water in the lateral culverts is regulated by vertical valves. When it is necessary to repair the valves, the lateral culverts can be shut off separately by means of sliding timbers.

The lock gates are constructed as mitering gates and are driven, like the valves, by means of electric machinery placed in chambers in the lateral masonry and sunk entirely under the plane of the lock. The locks are, moreover, provided with electrically driven capstans, with bollards and anchor hooks, with windlasses for hoisting the ship's hawsers, with fender chains to protect the gates against collisions, with appliancies for shutting off the locks when they are to be tapped dry, with ladders in the lateral walls, and with electric illumination and signaling apparatus on the plane of the lock. All the electric machinery, excepting the capstans, and also the illumination and the signal lamps, are operated from operating boxes erected on the lock plane. Cables are carried in cable tunnels under the locks. At the entrances to the locks are arranged towing-paths and landing piers, made partly of stone, partly of wood.

## 10. — **TOWING-PATHS**

In order to facilitate the towing of sailing vessels and barges from land by men or horses, a gravelled towing-path, with a width of 2.5 metres, has been arranged along one side in the artificial reaches of the Canal.

## 11. — **LIGHTHOUSES**

The lights along the Canal are of the Aga type, erected on dolphins or, in certain cases, on masonry foundations.

The lights are of hree types : athwart, aline, and sector lighthouses.

## 12. — DURATION OF THE RECONSTRUCTION

The works have in the main been executed by a directly employed staff, but certain excavation and masonry works were assigned to contractors. Moreover the larger iron constructions and machinery were executed and erected by contractors, with only a couple of exceptions, by Swedish Iron Works. The reconstruction has, as a whole, been carried out in 7 years, and the new passage was opened for the fraffic of vessels with a draught of 4 metres on October 25 a. c., when it was inaugurated by His Majesty King Gustaf V.

The new Canal has opened up direct navigation between the harbours on the big Lake of Vänern and the sea-ports of Europe, to the great advantage of International commerce.

## 13. — EXTENSION OF WATERWAYS IN SWEDEN

By a Bill passed this year the Riksdag has also voted a grant for the commencement of the extension of the Södertälje Canal, connecting the Baltic and the big Lake Mälaren, at the mouth of which, as we know, Stockholm is situated. Thus, when the reconstruction of this Canal has been completed, as it is to be within a few years, the two biggest lakes of Sweden will be accessible to modern sea-going vessels.

A further proof of the interest which the State Authorities in Sweden are devoting to the development of water traffic, is that a Commission has been appointed this year (the necessary grant having been voted by the Riksdag), to set on foot an investigation with regard to the requirement of further waterways in Sweden. Among the problems which this « Royal Canal Commission » is to deal with, is the question of arranging the so-called « *Svea Canal* », which is intended to connect the Lakes of Vänern and Mälaren.

The Royal Canal Commission consists of the following members :

*Colonel Hansen*, Director-General, Chairman;
*Major Fredrik Enblom*, of the Board of Highways, Private Railways and Water Constructions ;
*Mr. J. A. Appelqvist*, Director.

Stockholm. November 1916.

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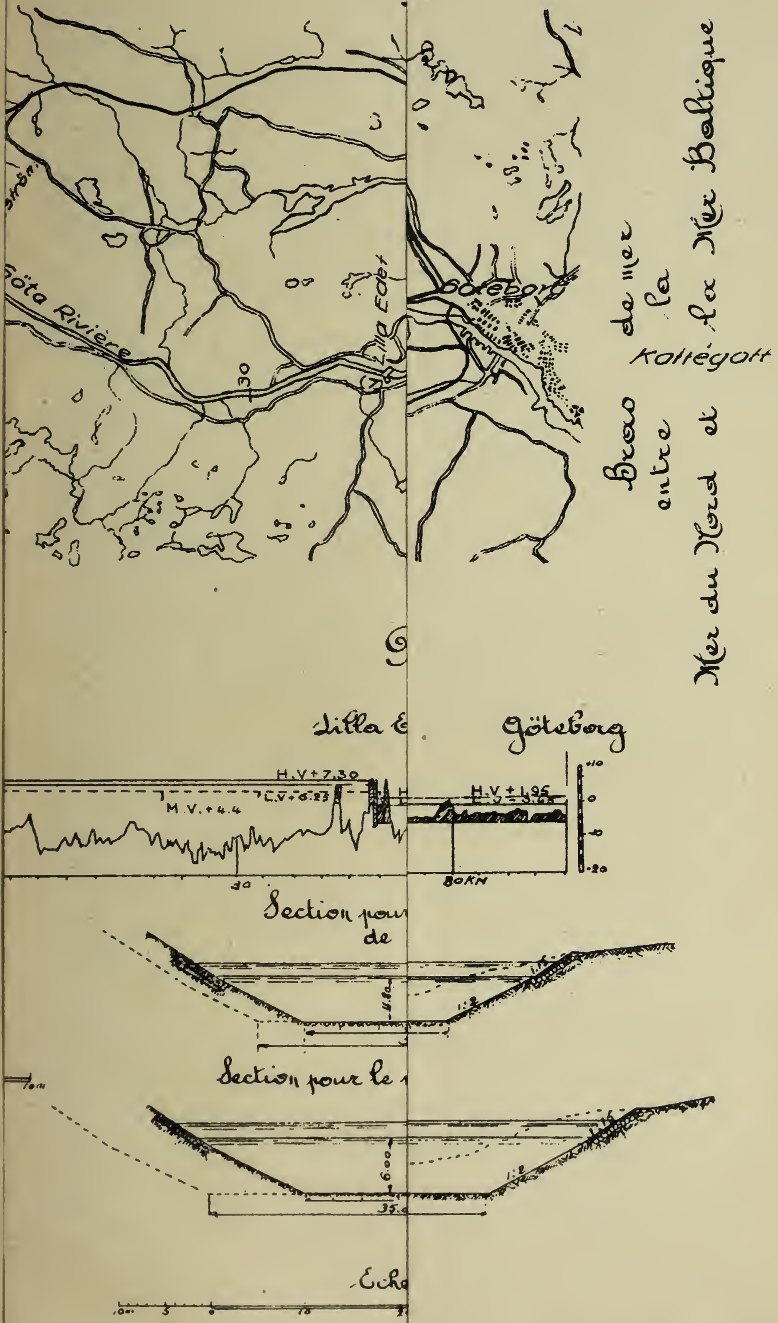

Association Internationale Permanente
des
# Congrès de Navigation.

Navigation intérieure.

Notice
par
J. V. Hansen

# Canal de Trollhättan.
reliant le lac Väner au Kattegat

Plan Profil en long et coupes transversales.

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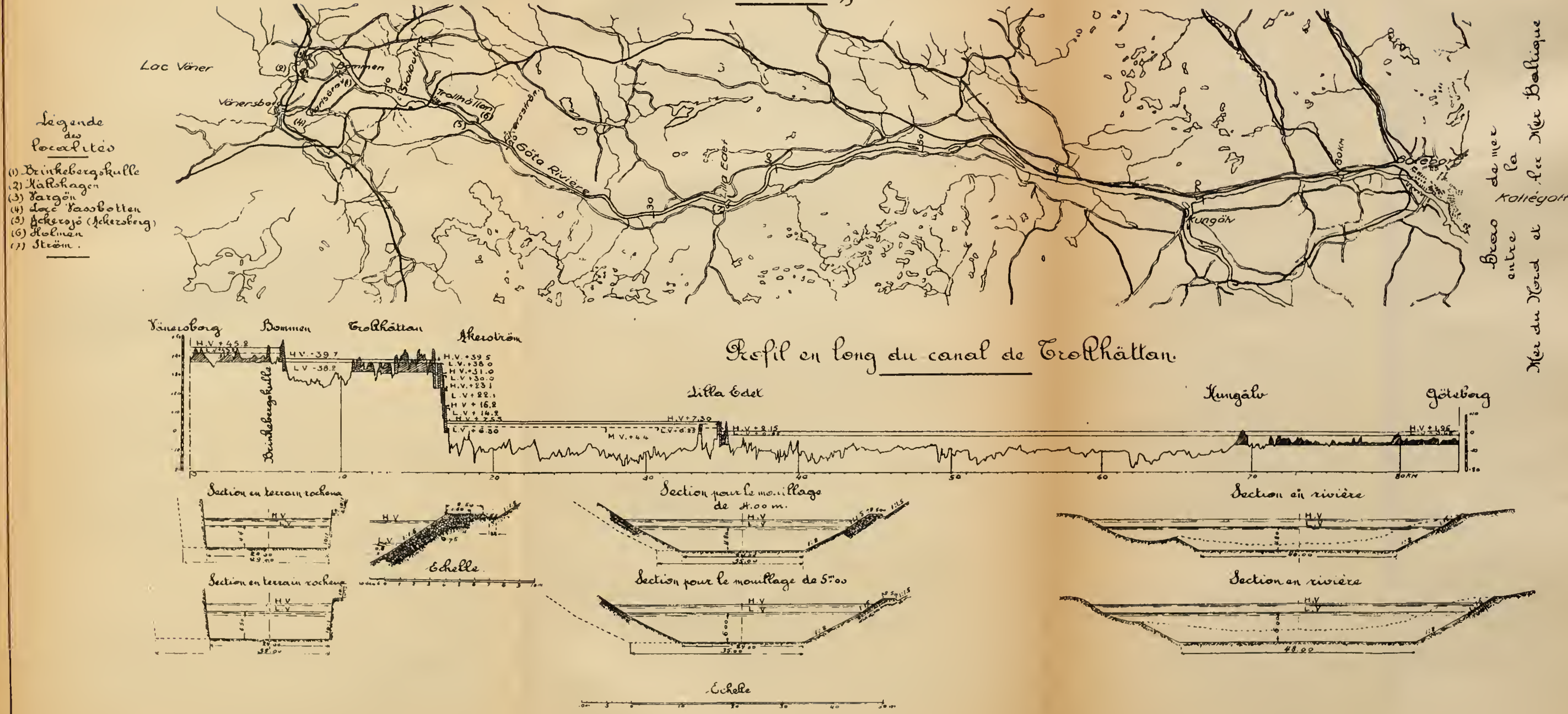
## Plan relatif au tracé du nouveau canal de Trollhättan reliant le lac Väner et le Kattegat.



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